ECE 322L
Electronics 2

01/28/20 - Lecture 3

Biasing configurations 1

Updates

- Remember to download the complete and revised version of the lecture slides <u>after</u> the lecture
- Check the lecture folder for solutions to the in-class problems
- First homework will be assigned on Thu
- Safety briefing within the lab sessions, this week
- Lab 1 starting this week. The assignment is posted on UNM learn (see the Labs folder)
- An updated syllabus is posted in UNM Learn
- The design project assignment is on UNM Learn

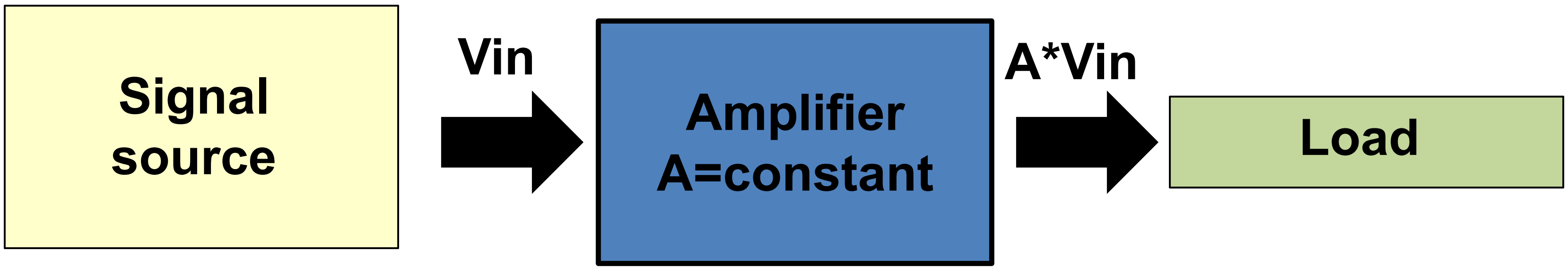
Overview of Lecture 3

- DC analysis of transistor behavior and elements of bias design for amplifiers (Neamen 3.2-S&S 5.3).
- Examples of biasing circuits 1

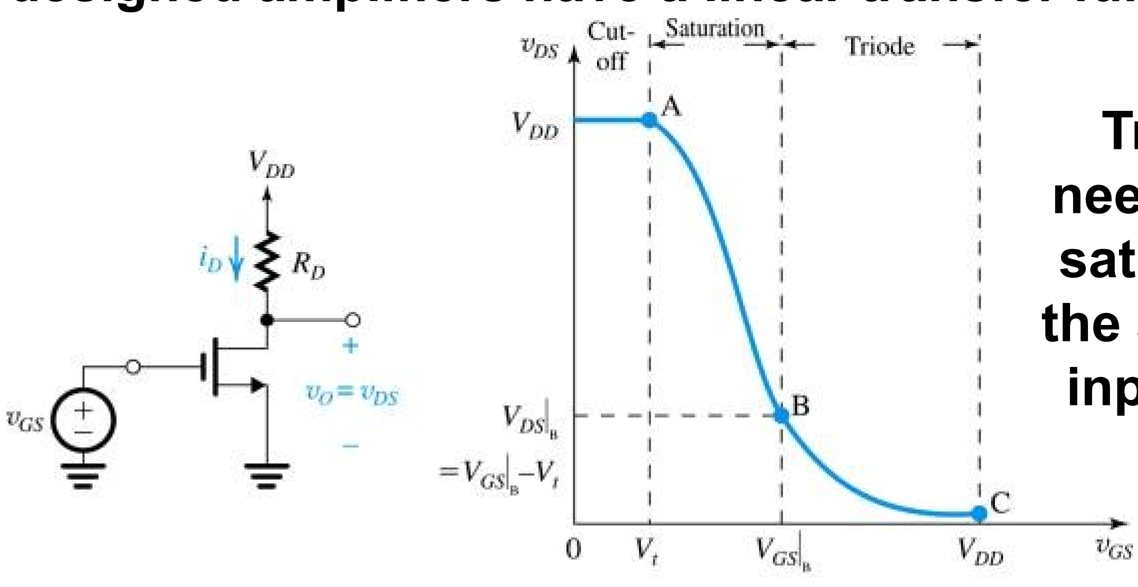
(Neamen 3.2,3.4, S&S 5.3, 5.4, 5.7)

Transistors as Amplifiers

The job of an amplifier is to increase the amplitude of an input signal without altering its waveform or distorting it



Well-designed amplifiers have a linear transfer function

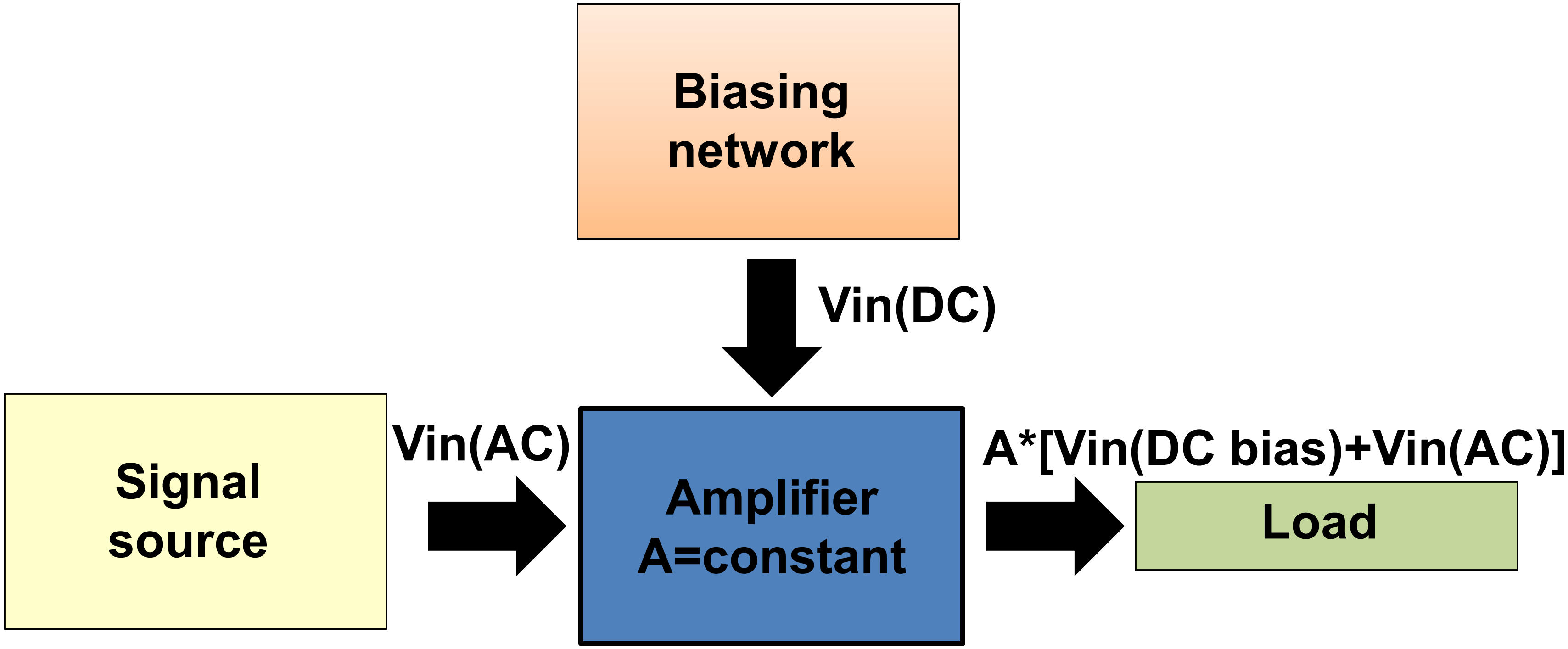


(a) (b)

Transistor needs to be in saturation for the all range of input signals

Transistors as Amplifiers

Operation of the transistor in saturation is forced by a DC circuit which is typically called the biasing network.



Transistor in Response to Bias and Signal

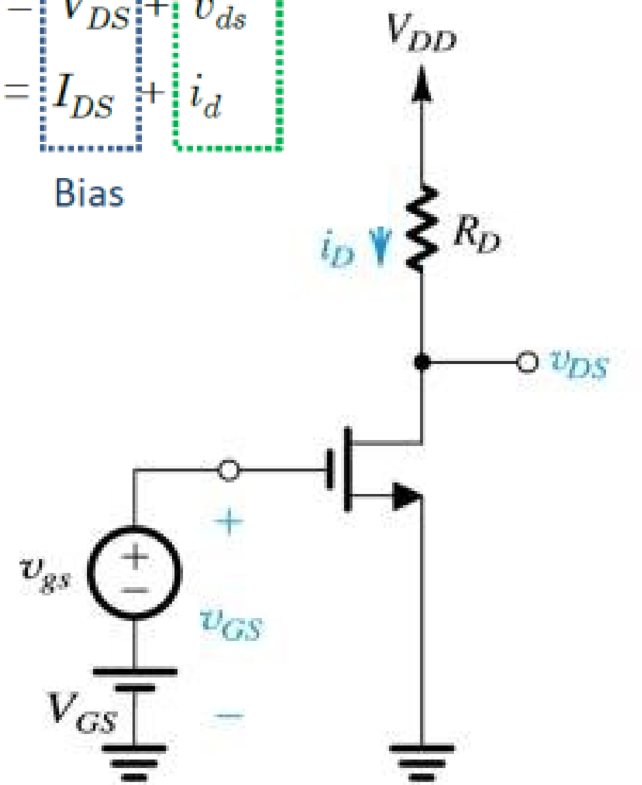
Signal and response

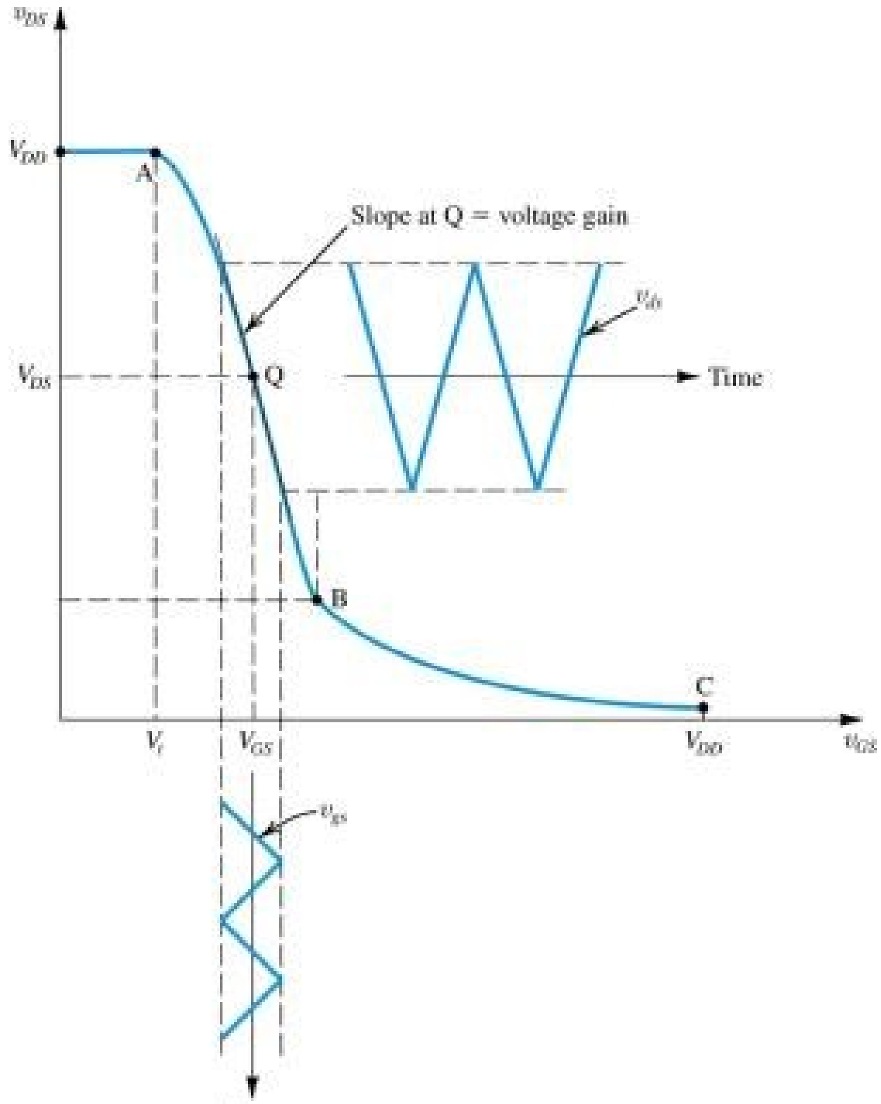
$$v_{GS} = V_{GS} + v_{gs}$$

$$v_{DS} = V_{DS} + v_{ds}$$

$$i_D = I_{DS} + i_d$$

Bias





Biasing a Transistor

V_{GS}, R_D and V_{DD} force the transistor to operate at a specific $V_{DS}=V_{DSQ}$, $V_{GS}=V_{GSQ}$, and $I_D=I_{DQ}$

$V_{DS}=V_{DSQ}$, $V_{GS}=V_{GSQ}$, and $I_D=I_{DQ}$ specify the Q point

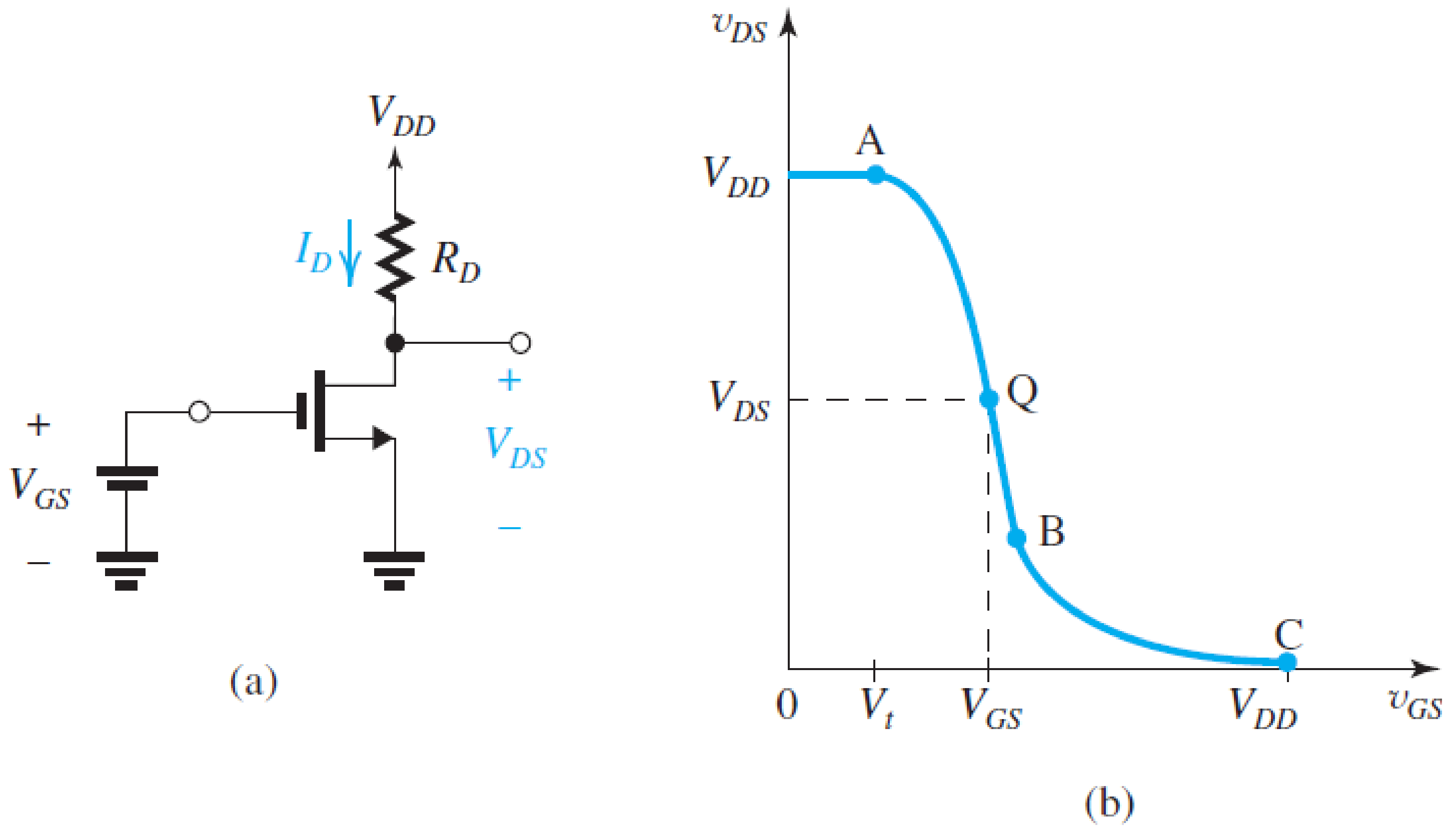
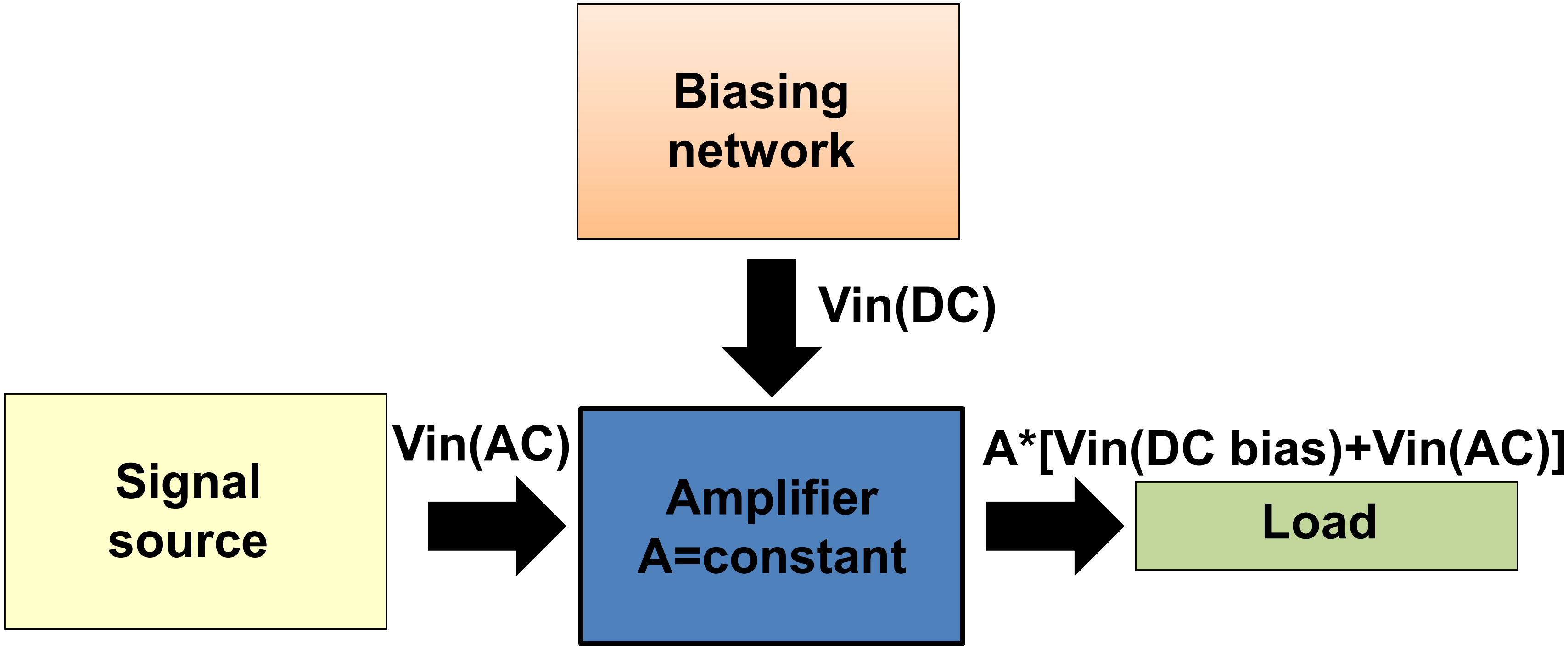


Figure 5.28 Biasing the MOSFET amplifier at a point Q located on the segment AB of the VTC.

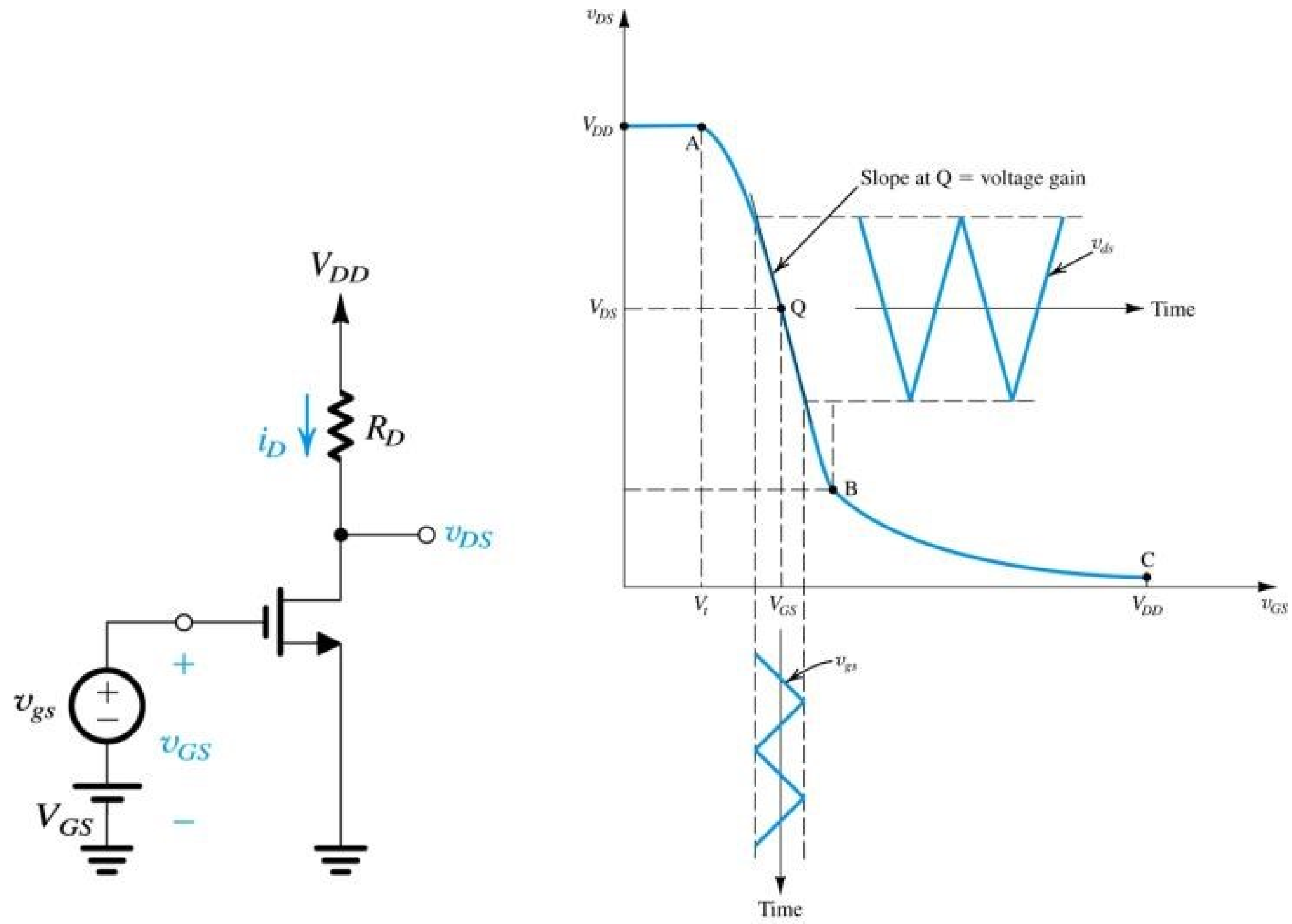
Transistors as Amplifiers



Designing/evaluating an amplifier is a two-step process

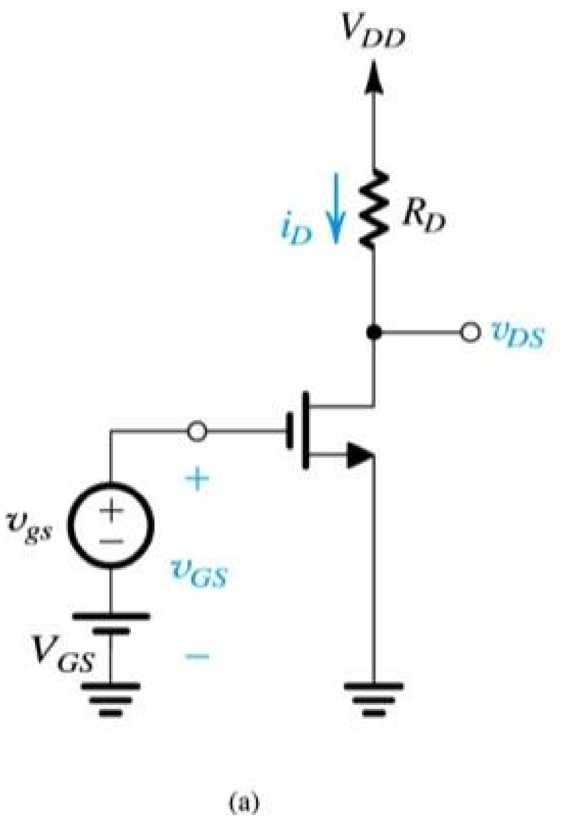
1. Design/Determine the operating point (DC)
2. Design/Determine response to the input (DC+AC)

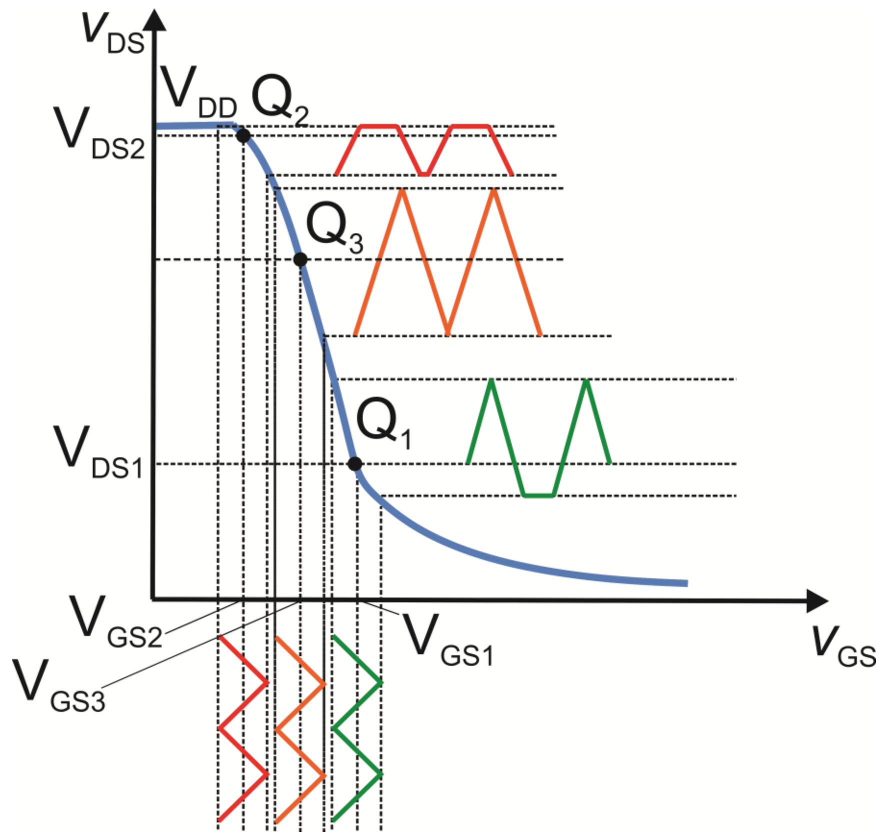
Desired Characteristics of the Operating Point



Stable and predictable V_{GS}, I_D and V_{DS} that ensure operation in the saturation region for all expected input signal levels.

Desired Characteristics of the Operating Point

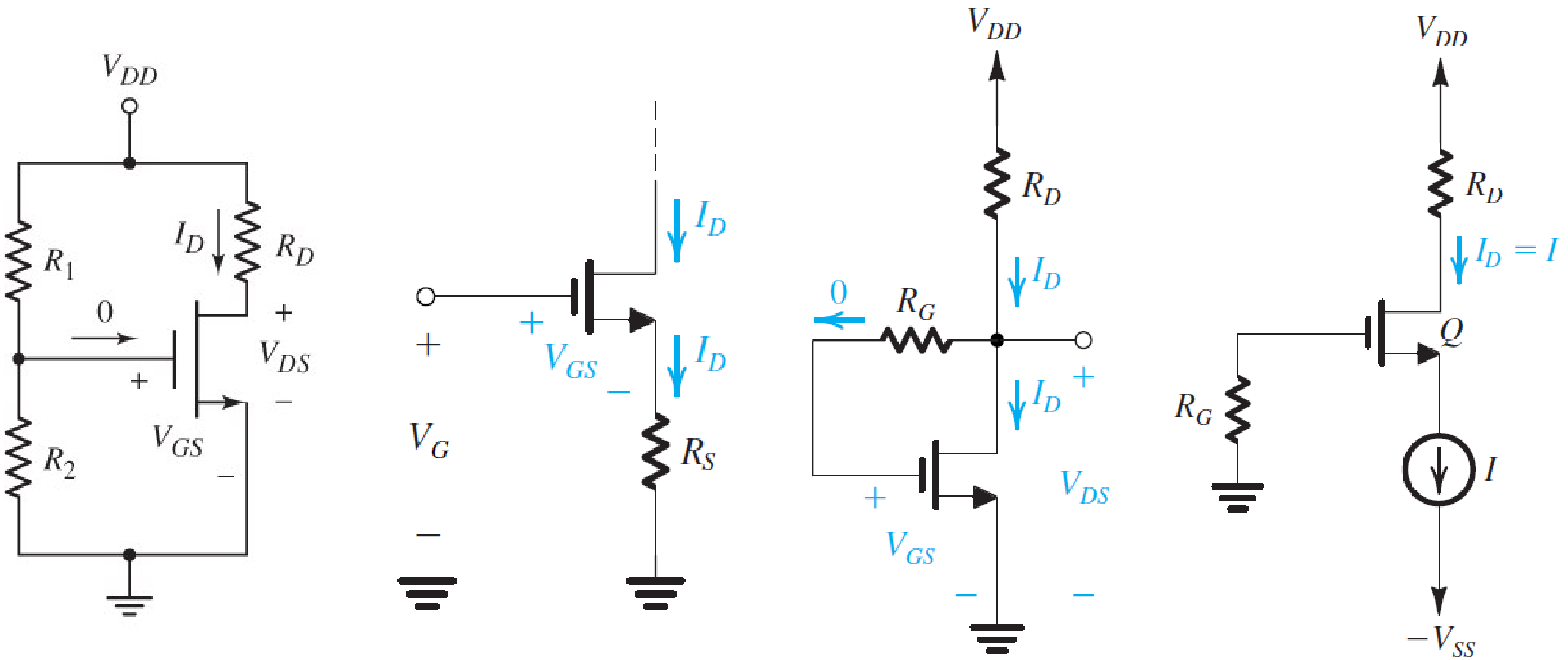




A Q point in the middle of the saturation region is desirable as it ensures that the transistor remains in saturation for a wide range of input signals.

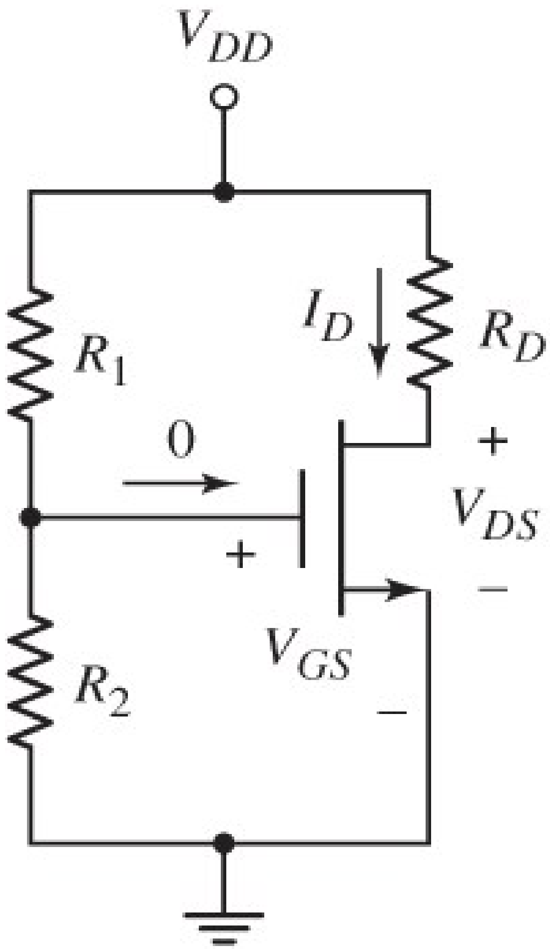
Biasing circuits

A well-designed biasing circuit for an amplifier should force a stable and predictable V_{GS}, I_D, and V_{DS} that ensure operation in the saturation region for all expected input signal levels.



<u>Four possible biasing circuits or configurations</u>

Biasing by fixing V_{GS}



$$V_{GS} = V_{DD}\frac{R_2}{R_1 + R_2}$$

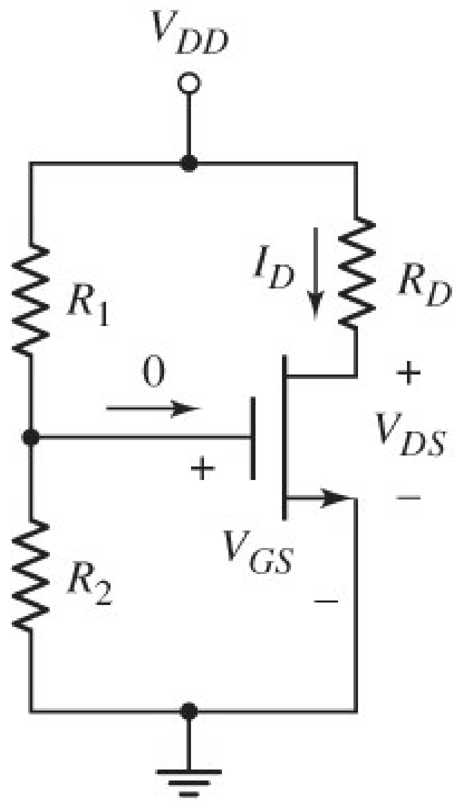
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_t)^2$$

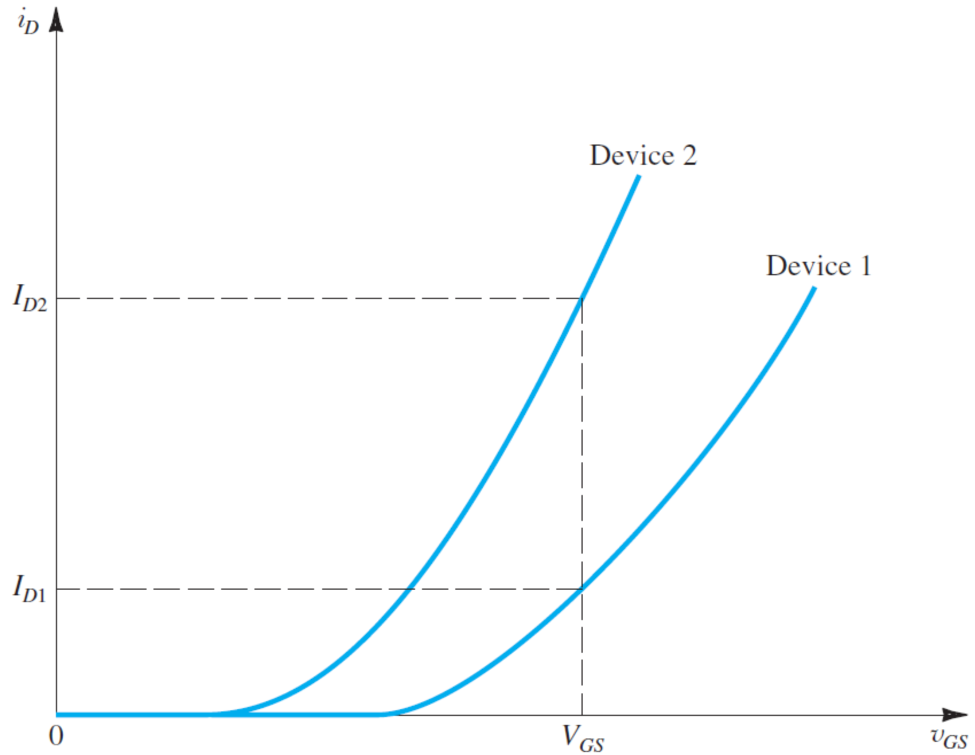
$$V_{DS} = V_{DD} - R_D I_D$$

By selecting appropriate valued of V_{DD}, R_1, R_2, and R_D one can force the FET to operate at some desired values of V_{GS}, I_D, and V_{DS}.

Biasing by fixing V_{GS}

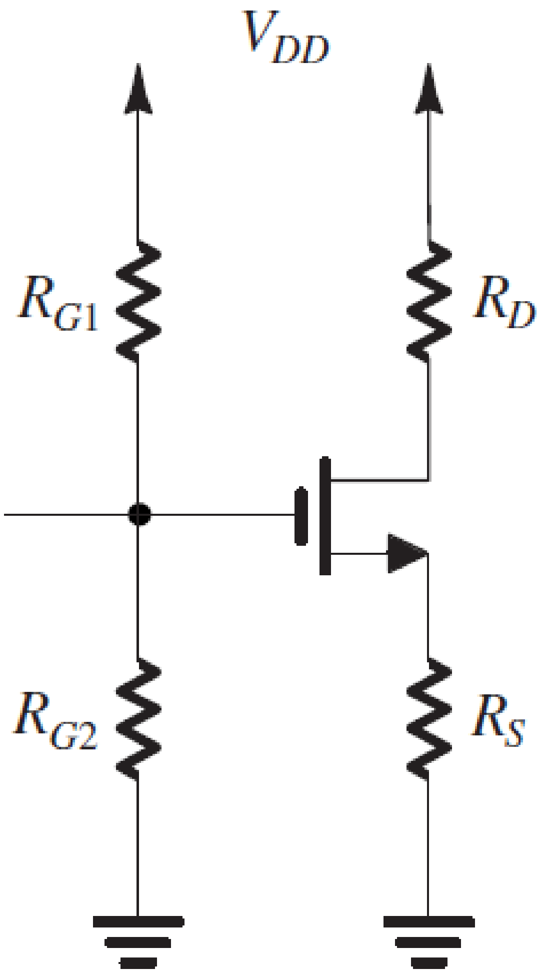
$$V_{GS} = V_{DD}\frac{R_2}{R_1 + R_2} \qquad I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_t)^2 \qquad V_{DS} = V_{DD} - R_D I_D$$





The Q point is not stable at a given temperature for two nominally identical devices

Biasing by fixing V_G and connecting a resistance to the source



$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}}$$

$$V_{GS} = V_G - R_S I_D \Rightarrow I_D = \frac{V_G - V_{GS}}{R_S}$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$\frac{V_G - V_{GS}}{R_S} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$V_{GS} = f(V_{DD}, R_{G1}, R_{G2}, R_S)$$

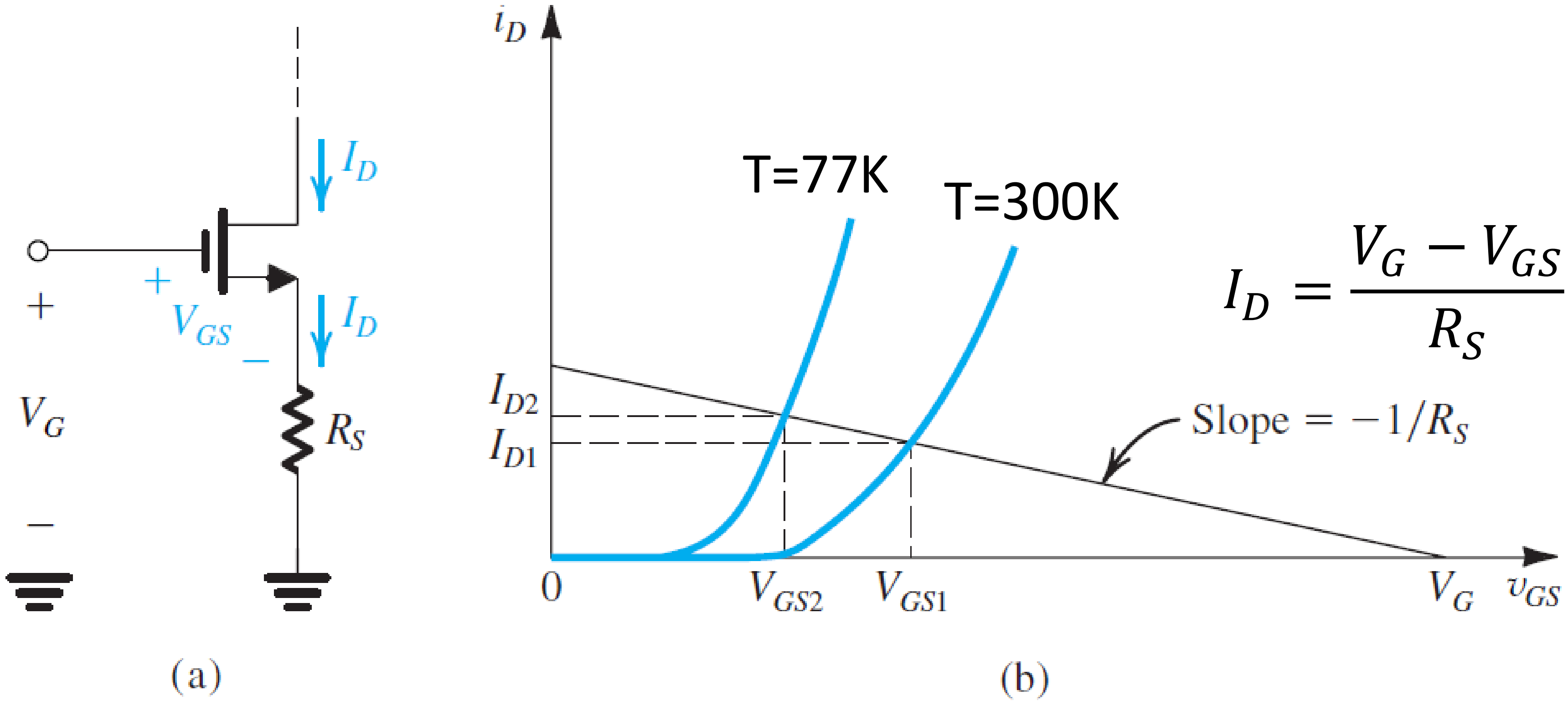
$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$V_{DS} = V_{DD} - (R_D + R_S) I_D$$

Biasing by fixing V_G and connecting a resistance to the source

R_S implements a feedback loop which keeps I_D relatively stable

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_t)^2 \quad V_G = V_{GS} + R_S I_D$$



$$I_D = \frac{V_G - V_{GS}}{R_S}$$

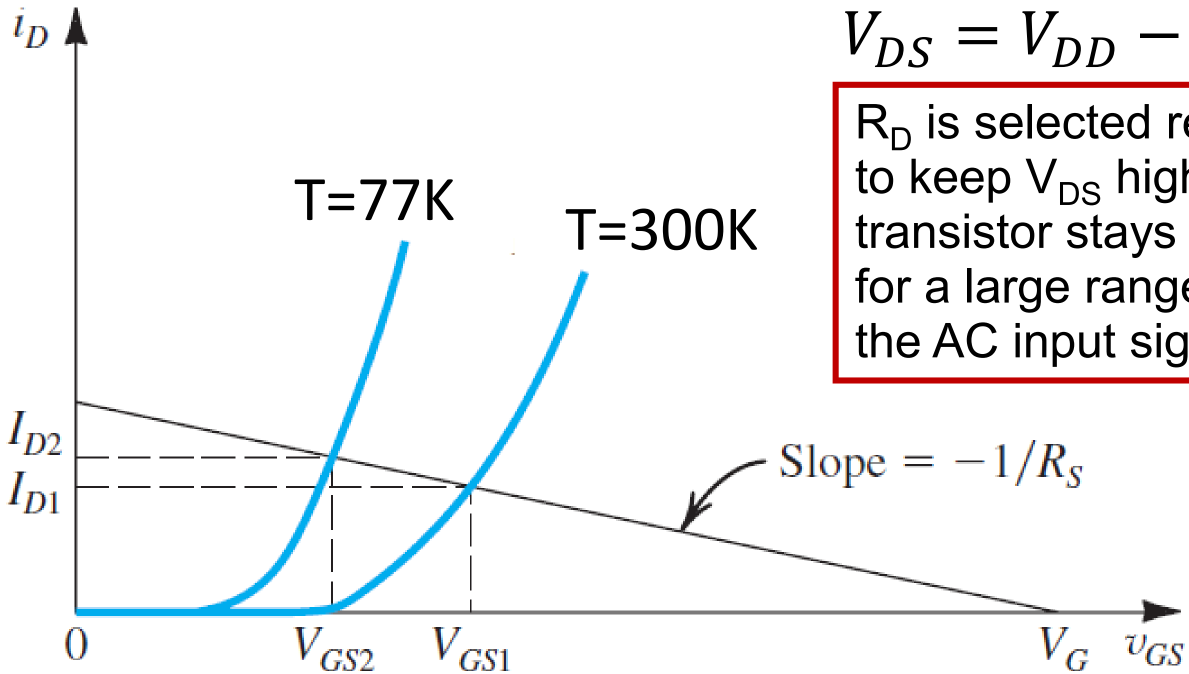
Biasing by fixing V_G and connecting a resistance to the source

Large V_G and R_S lead to an improved stability of the Q point.

Trade-off: At high R_S V_{DS} will decrease and the Q point will move towards the linear region.

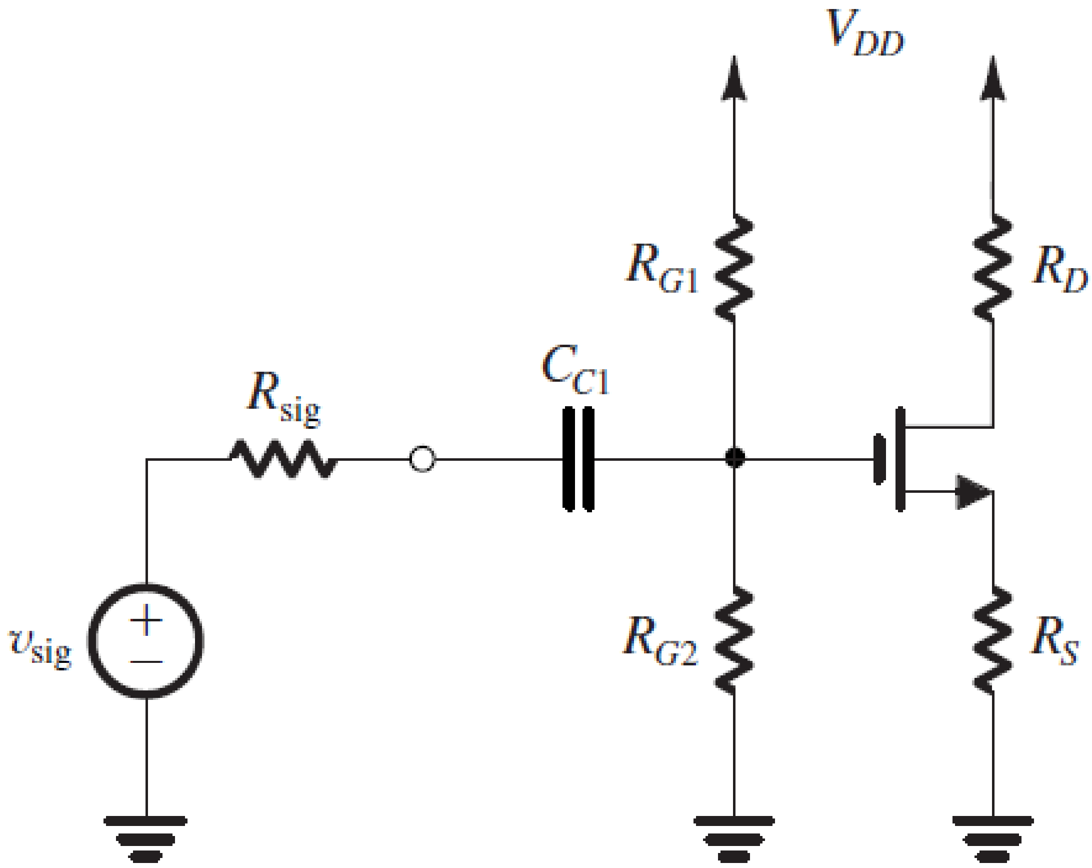
$$V_{GS} = V_G - R_S I_D \Rightarrow I_D = \frac{V_G - V_{GS}}{R_S} \qquad I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_t)^2$$

$$V_{DS} = V_{DD} - (R_D + R_S) I_D$$



R_D is selected relatively small to keep V_{DS} high so that the transistor stays in saturation for a large range of values of the AC input signal.

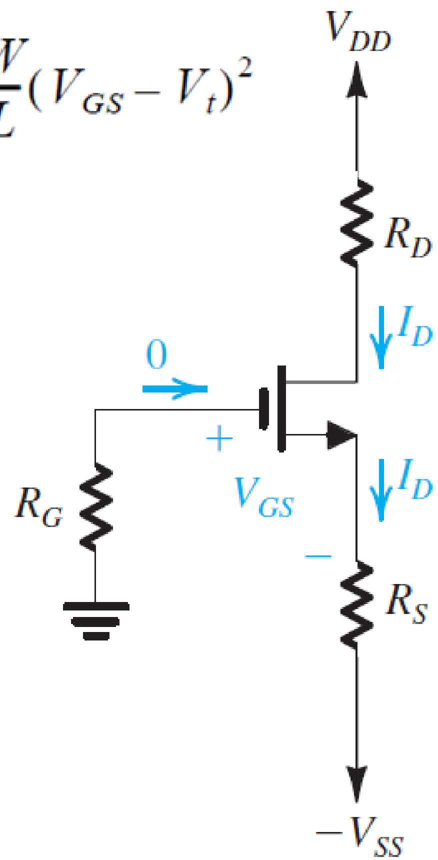
Example of a Practical Amplifier



In class problem

D5.34 Design the circuit of Fig. 5.52(e) to operate at a dc drain current of 0.5 mA and $V_D = +2$ V. Let $V_t = 1$ V, $k_n' W/L = 1$ mA/V^2, $\lambda = 0$, $V_{DD} = V_{SS} = 5$ V. Use standard 5% resistor values and give the resulting values of I_D, V_D, and V_S.

$$I_D = \frac{1}{2}\underbrace{\mu_n C_{ox}}_{k_n'}\frac{W}{L}(V_{GS} - V_t)^2$$



Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

Overview of lecture 4

- More examples of biasing circuits
  (Neamen 3.2,3.4, S&S 5.3, 5.4, 5.7)